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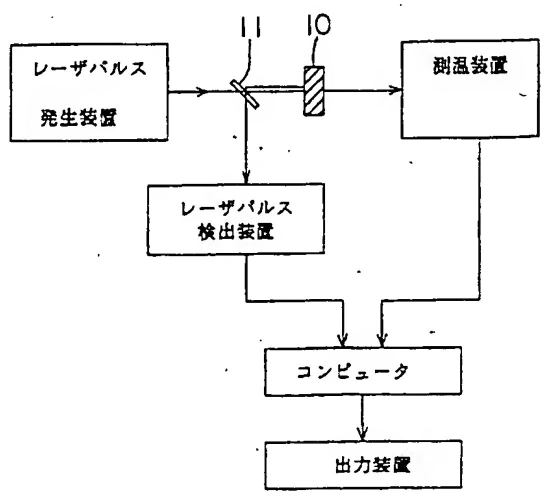
(54)【発明の名称】　レーザフラッシュ法を用いた熱定数の測定方法及びその装置

(57)【要約】

【目的】　高精度でかつ効率的に多層材料中の一層における未知の熱拡散率、比熱等の熱定数を決定することができ、しかも測定の環境条件に影響されることの少ないレーザフラッシュ法を用いた熱定数の測定方法及びその装置を提供する。

【構成】　熱拡散率及び比熱が未知の一層を含む多層材料１０の表面側からレーザフラッシュを照射して得られる裏面側の温度応答と、熱拡散率、比熱、及びビオー数を変数として含む理論温度応答とを比較し、前記熱拡散率、比熱、及びビオー数を求める。



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における時定数法のフロー図である。

【図６】３層からなる多層材料中の未知層の厚みを変化させた場合における時定数法の計算誤差を示す図である。

【図７】レーザフラッシュ法を用いた熱定数の測定法における直接法のフロー図である。

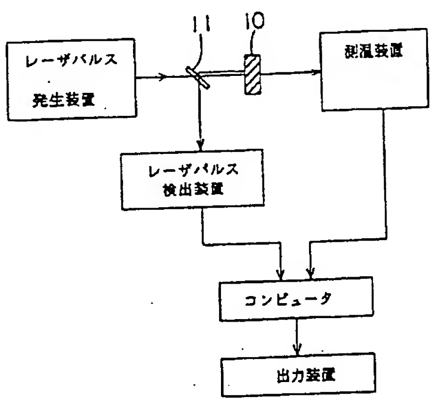
【図８】３層からなる多層材料中の未知層の厚みを変化させた場合における直接法の計算誤差を示す図である。

【符号の説明】

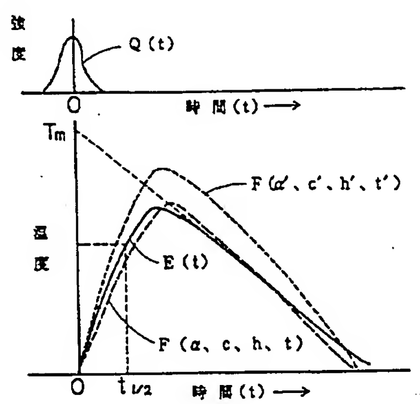
１０　多層材料

１１　ハーフミラー

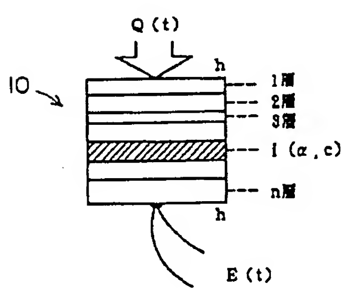
【図１】



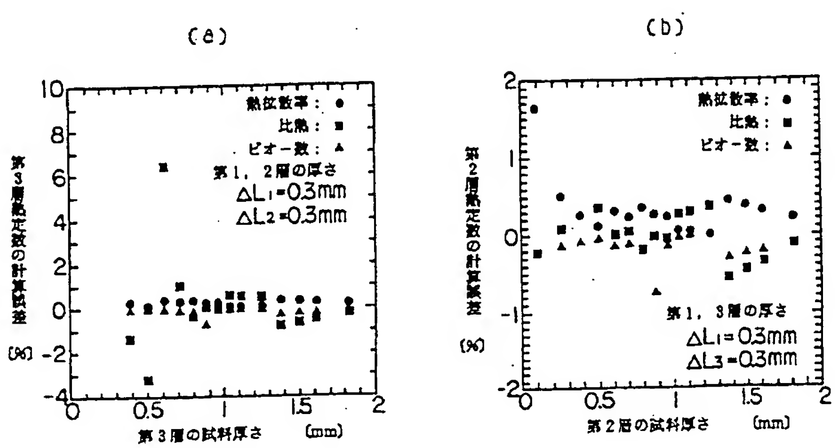
【図２】



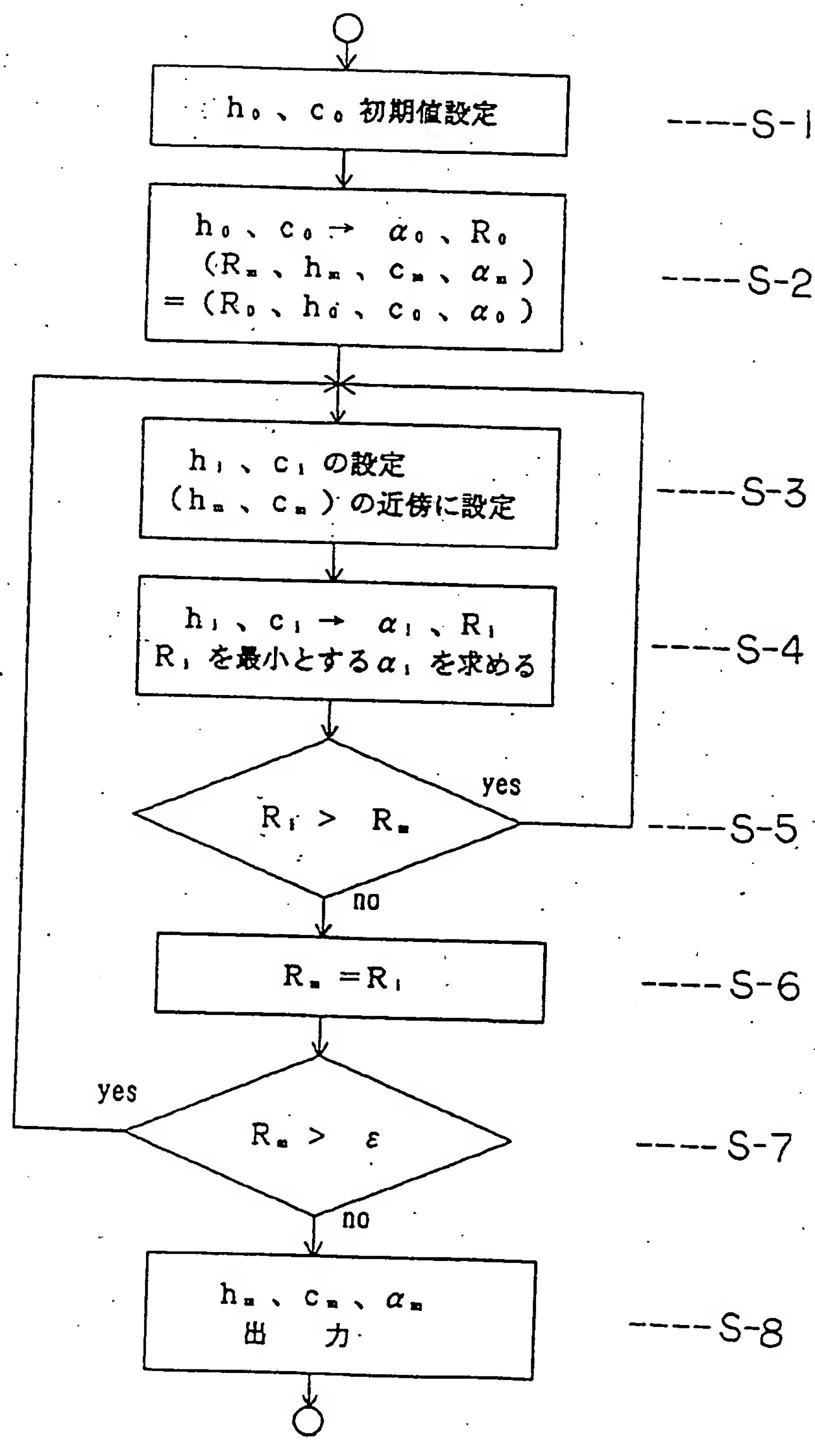
【図３】



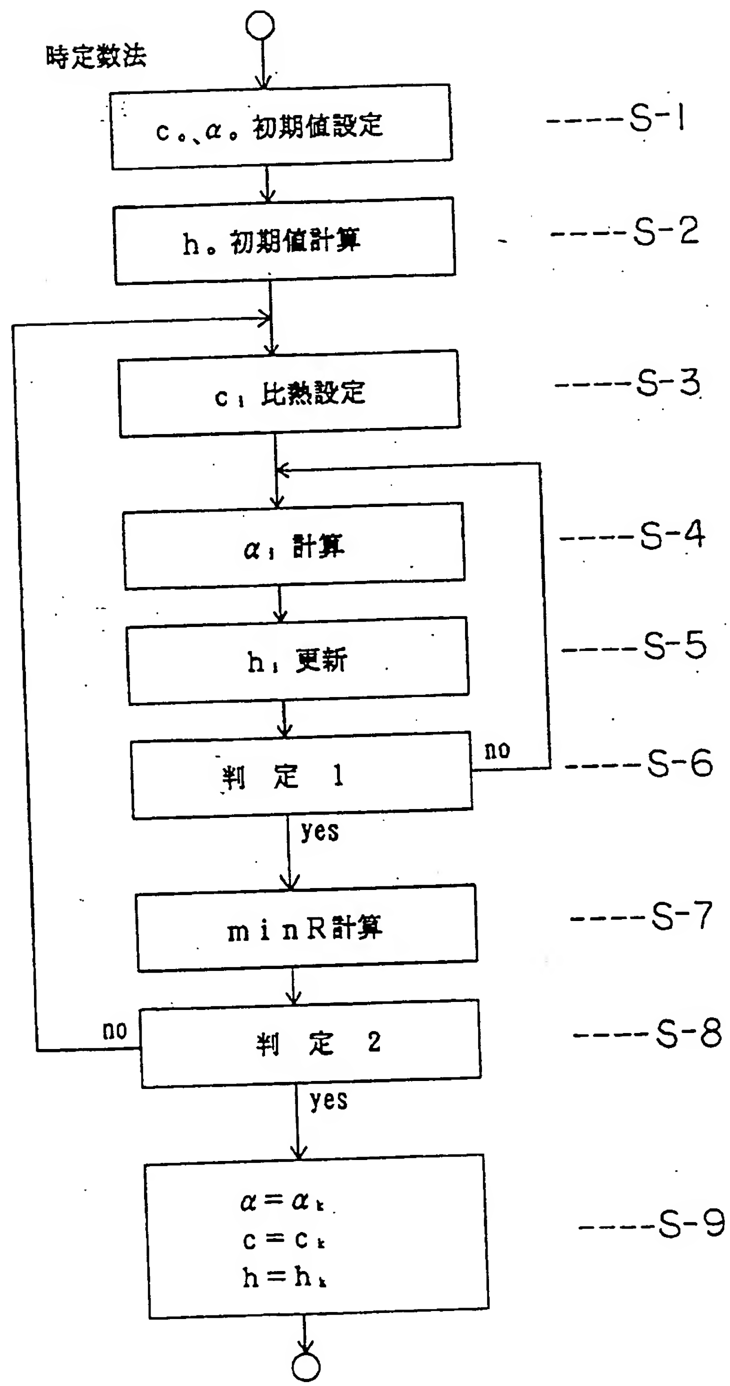
【図６】



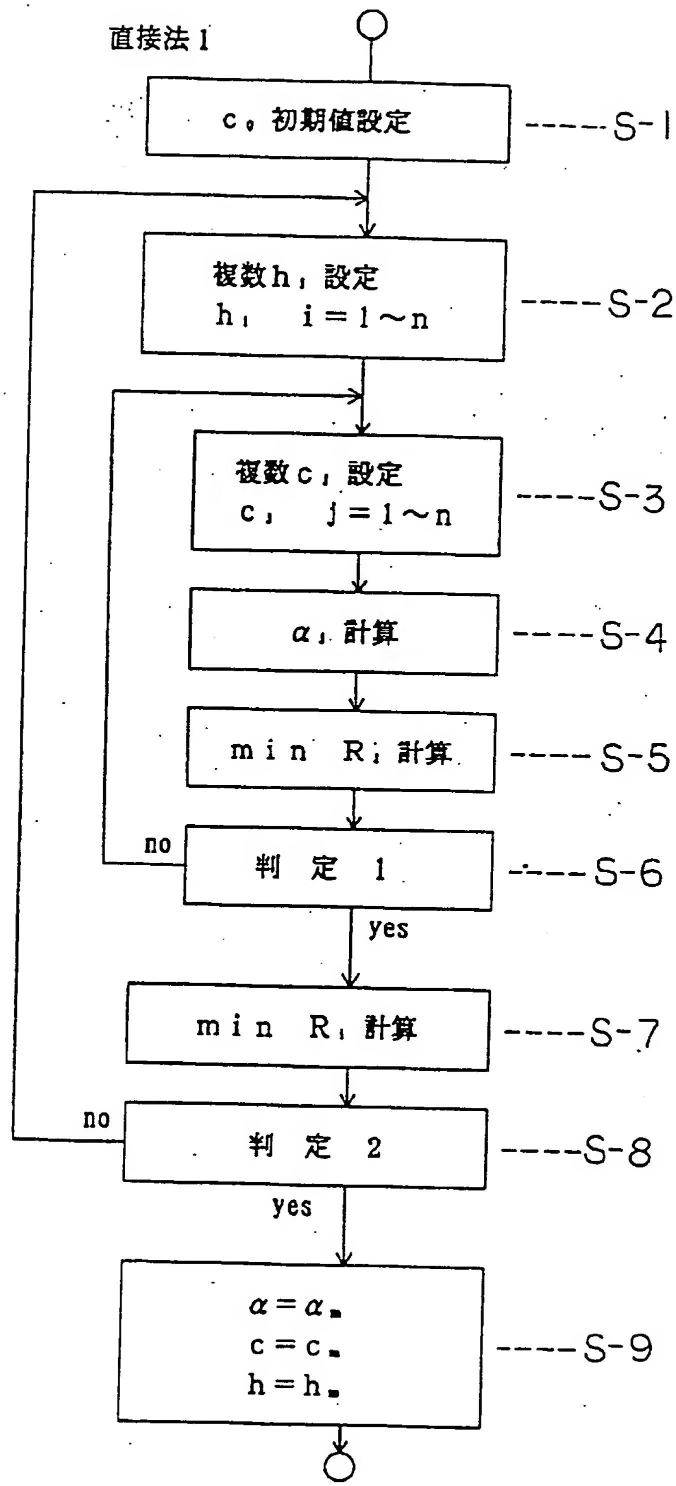
【図4】


h₀、c₀ 初期値設定
S-1
h₀、c₀ → α₀、R₀
(Rₘ、hₘ、cₘ、αₘ) = (R₀、h₀、c₀、α₀)
S-2
hᵢ、cᵢ の設定
(hₘ、cₘ) の近傍に設定
S-3
hᵢ、cᵢ → αᵢ、Rᵢ
Rᵢ を最小とする αᵢ を求める
S-4
Rᵢ > Rₘ
yes
no
S-5
Rₘ ＝Rᵢ
S-6
Rₘ > ε
yes
no
S-7
hₘ、cₘ、αₘ
出 力
S-8

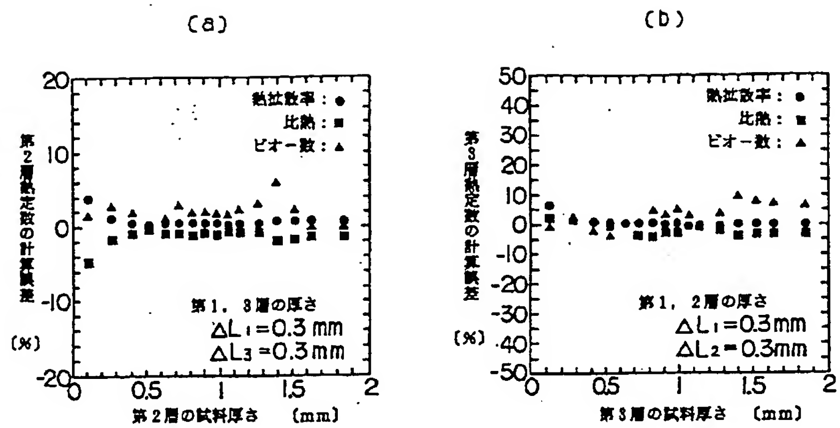
【図5】


時定数法
c_0、α_0 初期値設定
h_0 初期値計算
c_i 比熱設定
α_i 計算
h_i 更新
判　定　1
no
yes
ｍｉｎＲ計算
判　定　2
no
yes
$\alpha=\alpha_k$
$c=c_k$
$h=h_k$
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9

【図7】


直接法1
c_0 初期値設定
S-1
複数 h_i 設定
h_i　$i=1\sim n$
S-2
複数 c_j 設定
c_j　$j=1\sim n$
S-3
α_j 計算
S-4
min R_j 計算
S-5
判　定　1
S-6
no
yes
min R_i 計算
S-7
判　定　2
S-8
no
yes
$\alpha=\alpha_m$
$c=c_m$
$h=h_m$
S-9

【図8】


(a)
熱拡散率：●
比熱：■
ビオー数：▲
第2層熱定数の計算誤差
(%)
第1，3層の厚さ
ΔL1=0.3 mm
ΔL3=0.3 mm
第2層の試料厚さ (mm)
(b)
熱拡散率：●
比熱：■
ビオー数：▲
第3層熱定数の計算誤差
(%)
第1，2層の厚さ
ΔL1=0.3mm
ΔL2=0.3mm
第3層の試料厚さ (mm)

PATENT ABSTRACTS OF JAPAN

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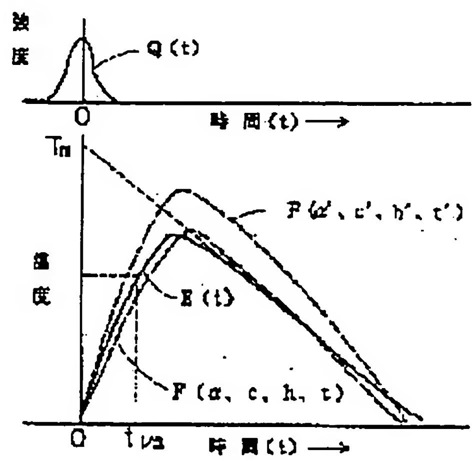
(54) MEASURING METHOD AND DEVICE FOR THERMAL CONSTANT USING LASER FLASH METHOD

(57)Abstract:

PURPOSE: To accurately and efficiently determine the thermal constants of an unknown layer in a multi-layer material by comparing the temperature response on the back face side obtained when a laser flash is radiated from the surface side of the multi- layer material and the theoretical temperature response including thermal diffusivity, specific heat, and Biot number as variables.



CONSTITUTION: The temperature response on the back face side obtained when a laser pulse is radiated from the surface of a multi-layer material containing one layer having unknown thermal diffusivity (α) and specific heat (c) is fed to a computer. It is compared with the theoretical temperature response F(α, c, h, t) or F'(α, c, h, p) including the thermal diffusivity α, specific heat (c), and Biot number (h) of the surface and back face of an unknown layer in the material set from documentary records as variables and calculated as a function of the time (t) or Laplace variable (p) of the temperature response. The thermal diffusivity α, specific heat (c), and Biot number (h) are set when the deviation R between the functions E(t) and E'(p) using the time (t) and variable (p) of the actual temperature response as variables becomes the minimum deviation Rm, then the thermal constants such as the

Biot number (h), specific heat (c), and thermal diffusivity α of the unknown layer can be obtained.

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[Date of final disposal for application]	
[Patent number]	
[Date of registration]	
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

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2. **** shows the word which can not be translated.
3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1] The measuring method of a heat constant using the laser flash method characterized by comparing the temperature response by the side of the rear face where a thermal diffusivity and the specific heat are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate with the theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable, and asking for the aforementioned thermal diffusivity, the specific heat, and the number of Biot.
[Claim 2] Another side is set to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, being set A and remaining one side as B. The 1st process which sets up the initial value of Above A and B, asks for C which makes the minimum deflection of the rear-face temperature response of the aforementioned multilayer material, and a theoretical temperature response, and sets up this deflection as initial value of minimum deviation, The 2nd process which sets up A and B with the aforementioned new multilayer material near A and B which give minimum deviation, The 3rd process which asks for C and deflection from which deflection with the theoretical temperature response of the aforementioned multilayer material and a rear-face temperature response serves as the minimum from A and B of the aforementioned multilayer material, The aforementioned deflection is compared with minimum deviation. when the aforementioned deflection is larger than minimum deviation When the 3rd process is repeated from the 2nd process and the aforementioned deflection turns into below minimum deviation The measuring method of a heat constant using the laser flash method according to claim 1 which has the 4th process which outputs a thermal diffusivity, the specific heat, and the number of Biot when minimum deviation reaches near [the] the minimal value by newly setting up this deflection as minimum deviation, and repeating the 3rd process from the 2nd process.
[Claim 3] The measuring method of a heat constant using the laser flash method according to claim 1 characterized by providing the following. The 1st process which sets up each initial value of a thermal diffusivity, the specific heat, and the number of Biot, asks for the deflection of a theoretical temperature response and rear-face temperature response including each of this initial value, and makes this thermal diffusivity, the specific heat, the number of Biot, and deflection a setting thermal diffusivity, the setting specific heat, the number of setting Biot, and setting deflection, respectively. The 2nd process which sets to A either the thermal diffusivity by which a setup was carried out [aforementioned], and the specific heat, sets remaining one side to B, and sets up new A near the above A. the calculation process which asks for A by which a setup was carried out [aforementioned], and B which makes the minimum deflection of the theoretical temperature response and the temperature response containing the number of setting Biot -- B -- asking -- this -- A and B -- the number of Biot -- updating -- the new number of setting Biot -- setting -- this -- the 3rd process which repeats this calculation process and defines a thermal diffusivity, the specific heat, and the number of Biot until it reaches near the deflection minimal value in the state where of A Whether this

deflection reached near the minimal value by asking for the deflection of the theoretical temperature response and temperature response containing the aforementioned thermal diffusivity, the specific heat, and the number of Biot, and the 4th process which judges, and outputs the thermal diffusivity, the specific heat, and the number of Biot in the time [process / 3rd / from the 2nd process of the above to] when deflection reaches near / the / the minimal value when having not reached.

[Claim 4] The measuring device of the heat constant of the aforementioned multilayer material using the laser flash method which compares the temperature response by the side of the rear face where the thermal diffusivity and the specific heat which are characterized by providing the following are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate with the theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable, and asks for the aforementioned thermal diffusivity, the specific heat, and the number of Biot. The 1st operation means which sets A and remaining one side to B, sets another side to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, sets up the initial value of Above A and B, asks for C which makes the minimum deflection of the temperature response and theoretical temperature response in the rear face of the aforementioned multilayer material, and sets up this deflection as initial value of minimum deviation. 1st calculation which sets up A and B with the aforementioned new multilayer material near A and B which give minimum deviation. From A and B of the aforementioned multilayer material, perform 2nd calculation which asks for C and deflection from which deflection with the theoretical temperature response of the aforementioned multilayer material and a rear-face temperature response serves as the minimum, and the aforementioned deflection is compared with minimum deviation. The 2nd operation means which newly sets up this deflection as minimum deviation when the aforementioned deflection is larger than minimum deviation, the above 1st and the 2nd calculation are repeated and the aforementioned deflection turns into below minimum deviation. The 3rd operation means which outputs a thermal diffusivity, the specific heat, and the number of Biot when it judged, and having not reached, and it repeats the above 1st and the 2nd calculation and a minimum deviation value reaches near [the] the minimal value, whether this minimum deviation reached near the minimal value, and.

[Claim 5] The measuring device of the heat constant of the aforementioned multilayer material using the laser flash method which compares the temperature response by the side of the rear face where the thermal diffusivity and the specific heat which are characterized by providing the following are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate with the theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable, and asks for the aforementioned thermal diffusivity, the specific heat, and the number of Biot. The 1st operation means which sets up each initial value of a thermal diffusivity, the specific heat, and the number of Biot, asks for the deflection of a theoretical temperature response and rear-face temperature response including each of this initial value, and makes this thermal diffusivity, the specific heat, the number of Biot, and deflection a setting thermal diffusivity, the setting specific heat, the number of setting Biot, and setting deflection, respectively. The 2nd operation means which sets to A either the thermal diffusivity by which a setup was carried out [aforementioned], and the specific heat, sets remaining one side to B, and sets up new A near the above A. the thermal diffusivity and the specific heat which calculate the A set up by the operation means of the above 2nd, and the B which make the minimum the deflection of the theoretical temperature response and the rear-face temperature response containing the number of setting Biot, and are obtained by the calculation result -- the number of Biot -- updating -- the new number of setting Biot -- setting -- this -- the 3rd operation means which repeats the aforementioned calculation and defines a

thermal diffusivity, the specific heat, and the number of Biot until it reaches near the Whether this deflection reached near the minimal value by asking for the deflection of the theoretical temperature response and rear-face temperature response containing the thermal diffusivity obtained by the operation means of the above 3rd, the specific heat, and the number of Biot, and the 4th operation means to judge, When the aforementioned deflection called for from the operation means of the above 4th has not reached near [the] the minimal value The 5th operation means which outputs the thermal diffusivity, the specific heat, and the number of Biot in the time when new A set up in the direction which gives the smaller minimal value is inputted into the operation means of the above 2nd and it reaches near [the] the minimal value.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention is highly precise and relates to the measuring method of the heat constant using the laser flash method which can determine heat constants, such as a thermal diffusivity of a sample, the specific heat, and the number of Biot, and its equipment.

[0002]

[Description of the Prior Art] As the thermal diffusivity of homogeneous material, and a measuring method of the specific heat, a laser flash method is a method which has spread quickly, compared with other methods, its measurement sample is little, is good, and has the feature in recent years at the place where highly precise measured value is obtained to a large temperature requirement. This method irradiates the pulse generated with laser in a sample side, measures the rear-face temperature of this sample using a radiation thermometer etc., and asks for a thermal diffusivity, the specific heat, etc. of a sample from the data of the temperature response characteristic.

[0003] It is described by delta T/delta t=alpha and (delta2 T/delta x2) the formula when an unsteady heat flow rate is in the interior of the 1-dimensional matter. T can calculate the solution to, when a thermal diffusivity and x are 1-dimensional coordinate variables and temperature and alpha set up initial condition and boundary condition. The thermal diffusivity alpha in this formula is defined by alpha=kappa / (Cp and rho) = kappa/c, and Cp, rho, and c are specific heat at constant pressure, density, and the heat capacity per unit volume (henceforth the specific heat), respectively. Therefore, if the specific heat at constant pressure and density of a measurement sample are known, it can ask for the thermal conductivity kappa of a sample using a thermal diffusivity alpha. And such a laser flash method is applied to multilayer material in recent years, and although the attempt which asks for the strange thermal diffusivity in multilayer material is made, since a formula becomes complicated, the satisfying result is not obtained by the problem of a calculation error being accumulated by repeating many calculation. Here, the thermal-diffusivity analysis method of monolayer material is described.

[0004] The general measuring method of the thermal diffusivity in a laser flash method is searched for as a thing which makes a theoretical solution in agreement with the measured-value data of measurement sample rear-face temperature. Namely, the theoretical temperature response T of the rear-face temperature of the sample by single dimension equation of heat conduction If Biot several h which is a parameter in connection with the thermal diffusivity alpha which is an unknown in the monostromatic in multilayer material, the specific heat c, and heat loss is assumed, respectively and a laser pulse is set to Q (t) The relational expression of T=F (alpha, c, h, t) can show strictly using Time t, and in being monolayer material, it becomes T=F (alpha, h, t). However, in order to ask for the aforementioned

unknowns alpha and h on the conditions which make the aforementioned theoretical temperature response F (alpha, c, h, t) agree to the pattern by actual rear-face temperature response E (t) The implicit function which contains a trigonometric function and an exponential function in a formula is contained, and since actual numerical calculation becomes very difficult, simplification technique is taken in calculation by limiting the data generally used for calculation using approximate value about a specific variable only to the data in a specific field etc. ** half-value value attainment time t1/2 as shown below as the analysis method of the thermal diffusivity by such laser flash method now The method, ** area method, the method of measuring the temperature rise of a measurement sample as the analysis method of ** specific heat, and asking for the specific heat, etc. are learned.

[0005] ** Half-value value attainment chronometric method half-value value attainment time t1/2 It is an initial temperature value to the highest rise temperature Tm on the temperature response curve in the rear face of material. It is the time taken for temperature to rise to a half value. And it is the highest rise temperature Tm on a temperature response curve. Half-value value attainment time t1/2 until temperature rises to a half value Thermal diffusivity alpha 0 according to half-value value chronometric method by alpha0 =1.36975L2 / (pi2 and t1/2) formula materialized when it assumes that it uses and there is no heat loss It calculates. Here, L is the thickness of a measurement sample. The aforementioned highest rise temperature Tm It extrapolates and asks for the decay curve after a temperature standup at pulse irradiation time. Subsequently, the relief coefficient k of this decay curve (inverse number of the time constant tau of a decay curve), and aforementioned aforementioned half-value value attainment time t1 / 2 Thermal diffusivity alpha 0 ask for the heat loss correction factor K by the product, and according to the aforementioned half-value value attainment time to this heat loss correction factor K It asks for the thermal diffusivity alpha amended having applied.

[0006] ** By calculating the deflection R of the average temperature in the specific section field set as the area-method temperature response, and the average temperature called for from a theoretical formula It is the method of asking for a thermal diffusivity alpha, the decay curve of the temperature response after a temperature standup is extrapolated at laser pulse irradiation time, and it is the highest rise temperature Tm. It carries out. The aforementioned deflection R is written for Biot several h as a function of a thermal diffusivity alpha using the time constant tau of this decay curve, and, subsequently it is the method of calculating a thermal diffusivity alpha by the conditional expression R= 0 about this deflection R.

[0007] ** The following procedures perform the method of computing the specific heat of this measurement sample by irradiating the laser flash plate of a constant rate at a measurement sample, and measuring temperature rise value deltaT of a measurement sample.

(a) Irradiate a laser pulse and measure absorbed-energy Q, after sticking a glassy-carbon board on the board (a sapphire board etc. is usually used) of specific heat known by silicone grease in the measurement room temperature of absorbed-energy Q. Absorbed-energy Q is expressed with a lower formula for each weight and specific heat from the measured value of temperature rise value deltaT' as known.

Q=(M1 C1+M2 C2+M3 C3) -deltaT' -- here -- M1, M2, and M3 respectively -- a glassy carbon, silicone grease, and the weight of sapphire -- it is -- C1, C2, and C3 They are a glassy carbon, silicone grease, and the specific heat of sapphire, respectively.

(b) the sample specific heat measurement in a room temperature -- irradiate a laser pulse like (a) which next sticks a glassy-carbon board on a sample by silicone grease in a room temperature, and measure temperature rise value deltaT Supposing the emissivity of a glassy carbon is equal, an absorbed energy will become equal and the following formula will be materialized.

Q=(M1 C1+M2 C2+Ms Cs0) -deltaT -- here -- Ms The weight of a sample and Cs0 are the specific heat of the sample under a room temperature. Therefore, the specific heat Cs 0 under the room temperature of a sample is given by the following formula using Q for which it

asked by (a).
The temperature rise [irradiate a laser pulse at the specific-heat-measurement sample simple substance of a 0= (Q-delta T-1-M1 C1-M2 C2)/Ms / Cs / (c) hot sample, and] value deltaT0 under a room temperature and an elevated temperature, and deltaT1 It measures, respectively. At this time, it is Q'=Cs0Ms deltaT0 and Q"=Cs1Ms deltaT1, supposing the absorbed energy of a sample does not change with temperature, it will become Q'=Q", and the specific heat of a sample is given by the following formula from this.
When the absorption coefficient of a Cs1=Cs0deltaT0/deltaT1 laser pulse is small, material with a high absorption coefficient (carbon spray etc.) is applied and measured in a sample.
[0008]
[Problem(s) to be Solved by the Invention] However, since calculation becomes very complicated in case an above-mentioned method is applied by the analysis method of the thermal diffusivity in said laser flash method, and the specific heat when asking for the strange thermal diffusivity or the strange specific heat in multilayer material since it is carrying out for monolayer material, the element with which a calculation error is accumulated and a calculation error intervenes becomes large, and it becomes it is remarkable and difficult to calculate a value with a high precision. As shown in drawing 2 , temperature response E by the side of a rear face (t) is obtained by writing the intensity distribution of a laser pulse like Q (t) as a function of Time t, and irradiating this laser pulse from the front-face side of multilayer material. Drawing 3 is the cross section of the multilayer material which consists of n sheets, and Biot several h in the front face and rear face of the thermal diffusivity alpha in the i-th layer, the specific heat c, and multilayer material is an unknown, and it presupposes that all the heat constants and thickness about the thickness of the layer and the remaining layers are known.
[0009] And the theoretical temperature response T by the side of such a rear face is strictly written as T=F (alpha, c, h, t), and can calculate the deflection of the theoretical temperature response T and the temperature response E by giving the concrete numeric value of alpha, c, and h which are a heat-characteristic value in multilayer material. And the goodness of fit of the theoretical temperature response T and the temperature response E is so high that the aforementioned deflection is small, and the precision of the value of alpha, c, and h which are set up at this time becomes high. That is, deflection of therefore (alpha, c, h) with temperature response E (t) is [the F (alpha', c' h' t)] larger, and the direction serves as a numeric value with a high precision from F (alpha, c, h, t) shown in drawing 2 from (alpha', h', c'). However, since the formula of theoretical temperature response T=F (alpha, c, h, t) in multilayer material becomes complicated, it is very difficult to calculate the minimum value of such deflection strictly with a mathematical analysis means.
[0010] Moreover, the laser flash plate of the constant rate of ** is irradiated at a measurement sample, and there are the following troubles in the method of computing the specific heat of this measurement sample by measuring temperature rise value deltaT of a measurement sample.
(b) Although it is the conditions of measurement that a pulse energy does not change by irradiation repeatedly, the guarantee does not exist.
(b) Although the absorption coefficient of a sample needs to be fixed to temperature, the guarantee does not exist. Moreover, although the application material which raises an absorbed energy does not need to deteriorate to an elevated temperature but an absorbed energy needs to be fixed, this guarantee does not exist, either.
(c) Since the absolute value of a temperature rise value is needed, measure with a thermocouple. Although a sample attaches in a sample with adhesives in the case of ceramics etc., the temperature as which these adhesives function is usually to about 1000K, and measurement of the specific heat cannot be performed at the temperature beyond it.
(d) Installation of this thermocouple is complicated and is work which requires skill. Usually,

since a quick response being required of measurement of a thermal diffusivity and the absolute value of temperature are unnecessary, it is measured by the radiation thermometer and, in measurement of the specific heat, it is required for the absolute value of temperature to measure with a required hatchet thermocouple. Therefore, when asking for thermal conductivity, you have to measure twice.

[0011] this invention was made in view of such a situation, can determine heat constants, such as a strange thermal diffusivity in the monostromatic in multilayer material, and the specific heat, and aims efficient with high precision at offering the measuring method of the heat constant using the laser flash method with moreover being influenced [little] by the environmental condition of measurement, and its equipment.

[0012]

[Means for Solving the Problem] The measuring method of a heat constant using the laser flash method according to claim 1 in alignment with the aforementioned purpose compares the temperature response by the side of the rear face where a thermal diffusivity and the specific heat are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate with the theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable, and it is constituted so that it may ask for the aforementioned thermal diffusivity, the specific heat, and the number of Biot.

[0013] The measuring method of a heat constant using the laser flash method according to claim 2 In the measuring method of a heat constant using the laser flash method according to claim 1 Another-side is set to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, being set A and remaining one side as B. The 1st process which sets up the initial value of Above A and B, asks for C which makes the minimum deflection of the temperature response and theoretical temperature response in the rear face of the aforementioned multilayer material, and sets up this deflection as initial value of minimum deviation, The 2nd process which sets up A and B with the aforementioned new multilayer material near A and B which give minimum deviation, The 3rd process which asks for C and deflection from which deflection with the theoretical temperature response of the aforementioned multilayer material and a rear-face temperature response serves as the minimum from A and B of the aforementioned multilayer material, The aforementioned deflection is compared with minimum deviation. when the aforementioned deflection is larger than minimum deviation When the 3rd process is repeated from the 2nd process and the aforementioned deflection turns into below minimum deviation While newly setting up this deflection as minimum deviation and repeating the 3rd process from the 2nd process, when minimum deviation reaches near [the] the minimal value, it is constituted so that it may have the 4th process which outputs a thermal diffusivity, the specific heat, and the number of Biot.

[0014] The measuring method of a heat constant using the laser flash method according to claim 3 In the measuring method of a heat constant using the laser flash method according to claim 1 Set up each initial value of a thermal diffusivity, the specific heat, and the number of Biot, and it asks for the deflection of a theoretical temperature response and rear-face temperature response including each of this initial value. The 1st process which makes this thermal diffusivity, the specific heat, the number of Biot, and deflection a setting thermal diffusivity, the setting specific heat, the number of setting Biot, and setting deflection, respectively, Remaining one side is set to B, being set either the thermal diffusivity by which a setup was carried out [aforementioned], and the specific heat as A. The 2nd process which sets up new A near the above A, and A by which a setup was carried out [aforementioned], And it asks for B according to the calculation process which asks for B which makes the minimum deflection of the theoretical temperature response and rear-face temperature response containing the number of setting Biot. this thermal diffusivity and the specific heat -- the number of Biot -- updating -- the new number of setting Biot -- setting -- this -- with the

3rd process which repeats this calculation process and defines a thermal diffusivity, the specific heat, and the number of Biot until it reaches near the deflection minimal value in the state where A was fixed It asks for the deflection of the theoretical temperature response and temperature response containing the aforementioned thermal diffusivity, the specific heat, and the number of Biot. It is constituted so that it may have whether this minimum deviation reached near the minimal value, and the 4th process which outputs the thermal diffusivity, the specific heat, and the number of Biot in the time when having not judged and reached and deflection reaches near [the] the minimal value [process / 3rd / from the 2nd process of the above to].

[0015] The measuring device of a heat constant using the laser flash method according to claim 4 The temperature response by the side of the rear face where a thermal diffusivity and the specific heat are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate, The theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable is compared. Are the measuring device of the aforementioned thermal diffusivity, the specific heat, and the heat constant of the aforementioned multilayer material using the laser flash method which asks for the number of Biot, and another side is set to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, being set A and remaining one side as B. The 1st operation means which sets up the initial value of Above A and B, asks for C which makes the minimum deflection of the temperature response and theoretical temperature response in the rear face of the aforementioned multilayer material, and sets up this deflection as initial value of minimum deviation, The 1st calculation which sets up A and B with the aforementioned new multilayer material near A and B which give minimum deviation, From A and B of the aforementioned multilayer material, perform 2nd calculation which asks for C and deflection from which deflection with the theoretical temperature response of the aforementioned multilayer material and a rear-face temperature response serves as the minimum, and the aforementioned deflection is compared with minimum deviation. When the aforementioned deflection is larger than minimum deviation, the above 1st and the 2nd calculation are repeated and the aforementioned deflection turns into below minimum deviation Whether the 2nd operation means and this minimum deviation which newly sets up this deflection as minimum deviation reached near the minimal value, and when it judged, and having not reached, and it repeats the above 1st and the 2nd calculation and a minimum deviation value reaches near [the] the minimal value It is constituted so that it may have the 3rd operation means which outputs a thermal diffusivity, the specific heat, and the number of Biot.

[0016] The measuring device of a heat constant using the laser flash method according to claim 5 The temperature response by the side of the rear face where a thermal diffusivity and the specific heat are obtained from the front-face side of the multilayer material containing a strange monostromatic by irradiating a laser flash plate, The theoretical temperature response which contains a thermal diffusivity, the specific heat, and the number of Biot as a variable is compared. It is the measuring device of the aforementioned thermal diffusivity, the specific heat, and the heat constant of the aforementioned multilayer material using the laser flash method which asks for the number of Biot. Set up each initial value of a thermal diffusivity, the specific heat, and the number of Biot, and it asks for the deflection of a theoretical temperature response and rear-face temperature response including each of this initial value. This thermal diffusivity, the specific heat, the number of Biot, and the 1st operation means that makes deflection a setting thermal diffusivity, the setting specific heat, the number of setting Biot, and setting deflection, respectively, Remaining one side is set to B, being set either the thermal diffusivity by which a setup was carried out [aforementioned], and the specific heat as A. A set up by the 2nd operation means which sets up new A near the above A, and the operation means of the above 2nd, and B which makes the minimum deflection of

the theoretical temperature response and rear-face temperature response containing the number of setting Biot are calculated. Update the number of Biot with the thermal diffusivity and the specific heat which are obtained by the calculation result, and the new number of setting Biot is defined. this -- with the 3rd operation means which repeats the aforementioned calculation and defines a thermal diffusivity, the specific heat, and the number of Biot until it reaches near the deflection minimal value in the state where A was fixed Whether this deflection reached near the minimal value by asking for the deflection of the theoretical temperature response and temperature response containing the thermal diffusivity obtained by the operation means of the above 3rd, the specific heat, and the number of Biot, and the 4th operation means to judge, When the aforementioned deflection called for from the operation means of the above 4th has not reached near [the] the minimal value When new A set up in the direction which gives the smaller minimal value is inputted into the operation means of the above 2nd and it reaches near [the] the minimal value, it is constituted so that it may have the 5th operation means which outputs the thermal diffusivity, the specific heat, and the number of Biot in the time.

[0017] the logarithm which took total of the square of the order square deflection which is total of the square both difference, the reverse square deflection which took total of the square of the difference of each inverse number, and the difference of each logarithm as deflection of a theoretical temperature response and a rear-face temperature response here -- it is applicable about square deflection and the deflection which consists of those combination Moreover, a Laplace transform can be performed to each measurement data and theoretical temperature response data, and data processing can be performed, or it can also calculate with live data. A difference and difference shall mean the so-called absolute value of a difference. Moreover, a specific allowed value, a specific reference value, and a permissible-level value are decision values for updating deflection etc., and are a value suitably set up according to the limit where the calculation error to need is permitted, respectively. The time of the aforementioned deflection reaching near [the] the minimal value means the state of stopping within the limits of the permissible-level value as which the difference before and behind updating is specified beforehand, even if it repeats updating calculation of deflection.

[0018]

[Function] The theoretical temperature response T on the rear face of a sample by single dimension equation of heat conduction can be strictly expressed as a function of Time t or the Laplace variable p as T=F (alpha, c, h, t) or T=F' (alpha, c, h, p), if Biot several h which is a parameter in connection with the heat loss in the front rear face of the thermal diffusivity alpha in the monostromatic in multilayer material, the specific heat c, and multilayer material is set up, respectively. In the measuring method of a heat constant using the laser flash method according to claim 1 to 3 Deflection R with function E (t) which makes a variable time t of the theoretical temperature response F (alpha, c, h, t) or F' (alpha, c, h, p), and the temperature response actually obtained, or function [which makes the Laplace variable p a variable] E' (p) is made into an index. It is minimum deviation Rm about thermal-diffusivity alpha and Biot severalh and the specific heat c. By setting up serially near the value to give, it is minimum deviation Rm. The true value of Biot severalh for which it updates and asks, the specific heat c, and a thermal diffusivity alpha can be acquired.

[0019] In the measuring method of a heat constant using the laser flash method according to claim 2, another side is set to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, being set A and remaining one side as B. The value of A and B more than a lot is set up near A and B which give minimum deviation. When it asks for C and deflection which make deflection the minimum to the combination of A and B, respectively, A and B are updated in the direction which compares minimum deviation and gives one by one more small minimum deviation and minimum deviation reaches near [the] the minimal value Since a thermal diffusivity, the specific heat, and the number of Biot are outputted, a

desired value can be calculated correctly and quickly by choosing two unknowns suitably according to a situation from three unknowns. In addition, in the following explanation, the case where A, the number of Biot, and a thermal diffusivity are assigned for the specific heat as B and C, respectively is shown. It is based on the flow view shown below at drawing 4 , and the procedure of asking for this thermal diffusivity alpha and the specific heat c is explained in detail.

[0020] first, the specific heat c which is the unknown in multilayer material as shown in drawing 3 which boils further and can be set, and Biot several h -- from a reference value etc. -- suitable -- setting -- each initial value c0 and h0 It sets up (S-1). And each initial value (c0 and h0) set up with the above S-1 is substituted for the theoretical temperature response F (alpha, c, h, t) or F' (alpha, c, h, p), and it asks by making into delta R/delta alpha= 0 the value of actual temperature response E (t) or alpha which makes the minimum square deflection R with E' (p). Here, alpha= delta R/delta 0 formula is an equation with one unknown of the form of g(alpha) = 0 which contains only alpha as a variable, and is the thing of the gestalt which can ask for this root alpha precisely by numerical-analysis methods, such as Newton's method. Thus, it is the initial value of alpha 0 and deflection R about the initial value of the thermal diffusivity alpha obtained R0 It carries out and the group (R0, alpha 0, c0, and h0) of these initial value is set up as a group (Rm, alpham, cm, and hm) of the temporary minimum value (S-2).

[0021] Then, the group (ci and hi) of a new value is set as the neighborhood of a point on the 2-dimensional flat surface displayed by (cm and hm) about the group (Rm, alpham, cm, and hm) of the minimum value (S-3). And ci and hi A value is substituted for the theoretical temperature response F (alpha, c, h, t) or F' (alpha, c, h, p), and it asks by making into delta R/delta alpha= 0 the value of alpha which makes the minimum square deflection R with actual temperature response E (t) or actual E' (p). It is Ri about the value of alphai and deflection R in the value of the thermal diffusivity alpha from which it is obtained at this time. It carries out and these groups (Ri, alphai, hi, and ci) are set up (S-4). Rm already set up as the minimum value in S-5 Ri obtained with the above S-4 comparing -- Ri Rm case it is large -- S-3 -- returning -- Ri Rm case it is small -- Rm =Ri ** -- carrying out -- the minimum value Rm Ri at that time It updates (S-6). The permissible-level value epsilon and the minimum value Rm which have been set up beforehand subsequently to S-6 It compares (S-7). Minimum value Rm When larger than the aforementioned permissible-level value epsilon, it returns to S-3. when smaller than the permissible-level value epsilon It considers that the group (Rm, alpham, cm, and hm) of the minimum value in the time is alpha, desired c, and desired h, it is outputted (S-8), and all the procedures that ask for the thermal diffusivity alpha in multilayer material and the specific heat c are terminated.

[0022] hi [in / S-3 / to following ** - **], and ci An example of the setting method is shown.

** Fix the number of Biot.

** Change the specific heat one by one, ask for a thermal diffusivity and deflection, and move the specific heat in the direction which compares the size of deflection and gives smaller deflection. The movement magnitude of this specific heat is made small as it approaches the deflection minimal value in the state where the number of Biot was fixed. The specific heat to the one number of Biot, a thermal diffusivity, and deflection are called for by this procedure.

** Change the set point of the number of Biot and perform the procedure of ** and **. ** Compare the size of the deflection which becomes settled for every number of Biot, and move the number of Biot in the direction which gives smaller deflection. The movement magnitude of this number of Biot is made small as it approaches the deflection minimal value. The number of Biot which gives the deflection minimal value with this procedure, the specific heat, and a thermal diffusivity are called for. It sets up so that it may become small as it is also possible to carry out the multi-statement of the number of Biot and the specific heat in the above-mentioned procedure, respectively and the deflection minimal value is approached in

setting interval deltaX of the number of Biot, and the specific heat in this case.

[0023] in addition -- as the judgment of S-7 -- in addition, a thermal diffusivity, the specific heat, and Biot -- a number of -- it is -- one of the deflection -- Xi ** -- carrying out -- the value in the time -- Xm ** -- it may carry out and you may judge on the conditions with which |(Xi-Xm)/Xm|<epsilon or |Xi-Xm |<epsilon is filled

[0024] In the measuring method of a heat constant using the laser flash method according to claim 3, either a thermal diffusivity and the specific heat can be set up first. The case where set the specific heat as below previously and it is asked for a heat constant is explained. Since the number of Biot is updated based on the relational expression which becomes settled with this specific heat and the value of the thermal diffusivity which gives minimum deviation after setting up the new specific heat near the specific heat which gives minimum deviation, the desired value of alpha, c, and h can be calculated correctly and quickly by making the specific heat c into a variable. This measurement procedure is explained in full detail below according to the flow view shown in drawing 5 . First, it is c0 and alpha 0 as each initial value of the specific heat c in the strange monostromatic in multilayer material, and a thermal diffusivity alpha. With reference to a reference value etc., it sets suitably (S-1). It is t1/2 in case there is no radiation loss about a thermal diffusivity. You may ask using a relation with an average thermal diffusivity. Subsequently, Biot several h initial value h0 The time constant tau obtained from a temperature response curve, and half-value value attainment time t1/2 It calculates from relational-expression h0 =f (t 1/2tau) using a value (S-2), and let each aforementioned initial value be the setting specific heat, a setting thermal diffusivity, and the number of setting Biot, respectively. The 1st process is completed by S-1 and S-2 above. This initializing method is not limited only to a measuring method according to claim 3. Then, the specific heat ci new near the aforementioned setting specific heat It sets up (S-3) and the 2nd process is ended. And the above S-2 and the value (ci and h0) set up by S-3 are substituted for F' (alpha, c, h, p) obtained by carrying out the Laplace transform of the theoretical temperature response F (alpha, c, h, t) or this. It asks by making into delta R/delta alpha= 0 the value of actual temperature response E (t) or alpha which makes deflection R with E' (p) the minimum, and is alphai about this. It carries out (S-4).

[0025] ci by which a setup was carried out [aforementioned] in S-5, and alphai The number hi of Biot updated by the hi =g (alphai and ci) formula using the value It obtains (S-5). Here, it is hi. Updating is calculable based on the following formulas.

cav= (sigma (rhoj and Cpj-delta lj))/ln alphaav=ln/(sigma (deltalj/(rhoj and Cpj-alpha j))) (-cav)

beta0 i=ln/(sqrt (alpha av-tau))

hi =beta0i- (sinbeta0i) (-1-(tanbeta0i)-1)

However, rhoj and Cpj-delta lj, and ln It shall be the density in the j-th layer, specific heat at constant pressure, the thickness of the j-th layer, and the thickness of all layers, and cav shall express the total of each item whose average of the heat capacity per unit volume of multilayer material and alphaav attach the average thermal diffusivity of multilayer material, and sigma by the n-th layer which is the last layer from the 1st layer, respectively. next, each value (a thermal diffusivity and the number of Biot --) acquired by the above S-4 and S-5 The above S-4 and S-5 are repeated until it judges by comparing the difference of either of the deflection, and each already set-up set point, or a ratio with each value of the difference based on a permissible-level-value (S-6) and satisfies a criteria. Finally the group of a desired heat constant (a thermal diffusivity, the number of Biot, specific heat) is obtained, and the 3rd process is finished here. The thermal diffusivity used by S-6 is the whole containing the thermal diffusivity of an unknown layer, or an unknown layer, or an average thermal diffusivity of some layers.

[0026] It asks for the deflection of the theoretical temperature response and temperature response containing the aforementioned thermal diffusivity, the specific heat, and the number

of Biot in S-7. A ratio or difference with this specific heat or this deflection and the aforementioned setting specific heat, difference with setting deflection and the setting specific heat, and setting deflection is calculated (S-8). when this ratio or difference is larger than a specific allowed value All procedures are finished, while outputting the thermal diffusivity, the specific heat, and the number of Biot in the time (S-9) and completing the 4th process, when it returns to S-3 and the aforementioned ratio or difference becomes below a specific allowed value [7 / S-/ from S-3 to].

[0027] The example of the setting method of the specific heat in S-3 is shown below. First, change of the specific heat set point asks for the number of Biot, a thermal diffusivity, and deflection for every specific heat. The size of this deflection is compared and the following specific heat is set up in the direction which gives small deflection. The variation of this specific heat is made small as it approaches the deflection minimal value. It is also possible to carry out the multi-statement of the specific heat in the above-mentioned procedure. In this case, setting interval deltac of the specific heat is made small as the deflection minimal value is approached.

[0028] In addition, in addition to this for the judgment of S-8, you may judge on the conditions with which |(Xi-Xm)/Xm |<epsilon or |Xi-Xm |<epsilon is filled by setting one of a thermal diffusivity and the numbers of Biot to X. Moreover, in carrying out the multi-statement of the specific heat in S-3, it asks for a thermal diffusivity, the number of Biot, and deflection from each specific heat by S-4, S-5, and S-6, the specific heat which gives the minimum deflection out of this is chosen in S-7, and it performs the same judgment in S-8. In not satisfying conditions, it carries out the multi-statement of the new specific heat in the direction which gives the smaller deflection at S-3.

[0029] In the measuring device of a heat constant using the laser flash method according to claim 4 Another side is set to C for either the aforementioned thermal diffusivity, the specific heat and the number of Biot, being set A and remaining one side as B. The 1st operation means which sets up the initial value of A and B, asks for C which makes the minimum deflection of the temperature response and theoretical temperature response in the rear face of multilayer material, and sets up this deflection as initial value of minimum deviation, The 1st calculation which sets up A and B with the aforementioned new multilayer material near A and B which give minimum deviation, From A and B of the aforementioned multilayer material, perform 2nd calculation which asks for C and deflection from which deflection with the theoretical temperature response of the aforementioned multilayer material and a rear-face temperature response serves as the minimum, and the aforementioned deflection is compared with minimum deviation. When the aforementioned deflection is larger than minimum deviation, the above 1st and the 2nd calculation are repeated and the aforementioned deflection turns into below minimum deviation Whether the 2nd operation means and this minimum deviation which newly sets up this deflection as minimum deviation reached near the minimal value, and when it judged, and having not reached, and it repeats the above 1st and the 2nd calculation and a minimum deviation value reaches near [the] the minimal value Since it has the 3rd operation means which outputs a thermal diffusivity, the specific heat, and the number of Biot Deflection R with the time function F of a theoretical temperature response (alpha, c, h, t), certain F[which it is and is this Laplace-transform form] ' (alpha, c, h, p), temperature response E (t) actually obtained, or E' (p) is made into an index. It is minimum deviation Rm about A and B. It sets up serially near the value to give and is minimum deviation Rm. It can update and the true value of the strange number of Biot, the specific heat, and a thermal diffusivity can be calculated by composition of a simple calculation means. and aforementioned the 1- the 3rd operation means consists of a computer constituted so that an actual operation might be performed according to the program set up beforehand

[0030] In the measuring device of a heat constant using the laser flash method according to

claim 5 Set up each initial value of a thermal diffusivity, the specific heat, and the number of Biot, and it asks for the deflection of a theoretical temperature response and rear-face temperature response including each of this initial value. This thermal diffusivity, the specific heat, the number of Biot, and the 1st operation means that makes deflection a setting thermal diffusivity, the setting specific heat, the number of setting Biot, and setting deflection, respectively, Remaining one side is set to B, being set either the thermal diffusivity by which a setup was carried out [aforementioned], and the specific heat as A. A set up by the 2nd operation means which sets up new A near the above A, and the operation means of the above 2nd, and B which makes the minimum deflection of the theoretical temperature response and temperature response containing the number of setting Biot are calculated. Update the number of Biot with the thermal diffusivity and the specific heat which are obtained by the calculation result, and the new number of setting Biot is defined. this -- with the 3rd operation means which repeats the aforementioned calculation and defines a thermal diffusivity, the specific heat, and the number of Biot until it reaches near the deflection minimal value in the state where A was fixed Whether this deflection reached near the minimal value by asking for the deflection of the theoretical temperature response and rear-face temperature response containing the thermal diffusivity obtained by the operation means of the above 3rd, the specific heat, and the number of Biot, and the 4th operation means to judge, When the aforementioned deflection called for from the operation means of the above 4th has not reached near [the] the minimal value Since it has the 5th operation means which outputs the thermal diffusivity, the specific heat, and the number of Biot in the time when new A set up in the direction which gives the smaller minimal value is inputted into the operation means of the above 2nd and it reaches near [the] the minimal value the number of Biot updates based on a thermal diffusivity and the specific heat -- having -- the time function F of a theoretical temperature response (alpha --) Deflection R with c, h, t, certain F[which it is and is this Laplace-transform form] ' (alpha, c, h, p) and temperature response E (t) actually obtained, or E' (p) is made into an index. It is minimum deviation Rm about the specific heat c. It sets up serially near the value to give and is minimum deviation Rm. It can update and the true value of the strange number of Biot, the specific heat, and a thermal diffusivity can be calculated by the repeat of a simple operation calculation means.

[0031]

[Example] Then, referring to the appended drawing, it explains per [which materialized this invention] example, and an understanding of this invention is presented. The block diagram of the laser flash plate equipment which applied the measuring method of a heat constant using the laser flash method which drawing 1 requires for one example of this invention here, Explanatory drawing of the measuring method of a heat constant with which drawing 2 used the laser flash method, explanatory drawing of the laser flash method with which drawing 3 uses multilayer material, The flow view of the direct method in the measuring method of a heat constant with which drawing 4 used the laser flash method, The flow view of the time constant method of the measuring method of a heat constant drawing 5 used the laser flash method, Drawing showing the calculation error of a time constant method when drawing 6 changes the thickness of the strange layer in the multilayer material which consists of three layers, The flow view of the direct method in the measuring method of a heat constant with which drawing 7 used the laser flash method, and drawing 8 are drawings showing the calculation error of the direct method at the time of changing the thickness of the strange layer in the multilayer material which consists of three layers.

[0032] First, the measuring device of heat constants, such as a thermal diffusivity using the laser flash method concerning the example of this invention shown in drawing 1 , the specific heat, and the number of Biot, is explained. This is equipment which measures the strange heat constant in the monostromatic contained in this multilayer material 10 by making a measurement sample into the multilayer material 10 using a laser pulse generator. By

generating of the pulse of an arbitrary wave being possible and choosing a special wave according to the range of the physical-properties value of the multilayer material 10, and the analysis method of a heat constant as occasion demands, a laser pulse generator can simplify calculation or can also raise now the accuracy of measurement in a specific field. The temperature response on the rear face of a sample is measured with the temperature measurement equipment by the radiation thermometer or the thermocouple.

[0033] The wave signal of the laser pulse which irradiated the aforementioned multilayer material 10 is incorporated by laser pulse detection equipment via the one-way mirror 11 prepared between this multilayer material 10 and the aforementioned laser pulse generator. Moreover, it is also possible by measuring the leakage light in the middle of the optical path of a laser beam to measure pulse shape. And the signal data from the aforementioned temperature measurement equipment and laser pulse detection equipment are downloaded to a computer, data processing which determines heat constants, such as a thermal diffusivity, the specific heat,,and the number of Biot, based on these signal data is performed, and the whole is constituted so that data and the result of an operation can be displayed on the output unit linked to a computer.

[0034] In order to analyze heat characteristics, such as a thermal diffusivity of the multilayer material 10, or the specific heat, using a laser flash method, a theoretical temperature response when the laser pulse Qf (t) is first irradiated by the multilayer material 10 is calculated. f (t) uses the function which standardized the integration value in all time domains as 1 here. It is possible to perform this analysis on the Laplace space which changes by the Laplace transform and is obtained, and to calculate the theoretical solution of a temperature response as follows.

[0035] First; thermal-diffusivity alphai [in / the i-th layer / as what the multilayer material 10 becomes from n layers], specific heat at constant pressure Cpi, density rhoi, and thickness deltaLi It sets. Therefore, thermal conductivity ki ki =alphai and Cpi-rho i It is expressed. Moreover, thickness Li from a front face to the boundary of the i-th layer and a ** (i+1) layer Li =deltaL1+deltaL2+ ... +deltaLi It becomes. The equation of heat conduction in the i-th layer in a laminar composite is deltaTi/(x t) delta t=alpha i and delta2 Ti/(x t) deltax2. It is written and initial condition is Ti =(x t) 0. Moreover, boundary condition is shown by Ti =(Li, t) Ti+1 (Li, t) and ki-delta Ti/(Li, t) deltax=ki+1 and deltaTi+1 / (Li, t) delta x, respectively. Therefore, the Laplace variable is set to p by performing a Laplace transform to these. The aforementioned equation of heat conduction as delta2 Ti / (x p) deltax2 = (p/alphai), and Ti (x p) Moreover, boundary condition is acquired, respectively as Ti =(Li, p) Ti+1 (Li, p) and ki-delta Ti/(Li, p) deltax=ki+1 and deltaTi+1 / (Li, p) delta x. And the set of equation of heat conduction by which the Laplace transform was carried out about all the multilayer material 10 is obtained by applying the same operation one by one until it results in the n-th last layer from the 1st layer.

[0036] The general solution of equation of heat conduction [in / the i-th layer / as mentioned above] is given by Ti =(x p) Ai exp(ri and x)+Bi exp (-ri and x). However, ri It is ri =sqrt (p/alphai) and they are Ai and Bi. It is an integration constant. And they are the integration constant Ai of the temperature formula of the i-th layer, and Bi from the boundary condition of the i-th layer and a ** (i+1) layer. Integration constant Ai+1 of the temperature formula of a ** (i+1) layer, and Bi+1 A formula 1 can be obtained in quest of a relation. It is Gi and i+1 here. It is the matrix expressed with a formula 2. Therefore, the coefficient of the 1st layer temperature and the coefficient of the n-th layer temperature have the relation expressed with a formula 3. Same analysis is performed using the conditions of the heat input in a front face and a rear face, and heat dissipation, finally, the temperature response Ts in the n-th layer, i.e., sample rear-face temperature, is given with a formula 4, and it is expressed by relational-expression T=F' (alpha, c, h, p) which includes three variables (thermal-diffusivity alphai, specific heat ci, and Biot severalh) in a formula. (However, the value h0 by the side of the

front face of the number of Biot and the value h1 by the side of a rear face are assumed to be equals.) h=h0 =h1)

[0037]

[Equation 1]

$$\begin{bmatrix} A_i \\ B_i \end{bmatrix} = G_{i,i+1} \begin{bmatrix} A_{i+1} \\ B_{i+1} \end{bmatrix} \quad \text{------------} \quad (数式1)$$

$$G_{i,i+1} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

但し

$$\begin{aligned} a &= (1+k_{i+1} r_{i+1} / k_i r_i) \exp(-r_i L_i + r_{i+1} L_i) / 2 \\ b &= (1-k_{i+1} r_{i+1} / k_i r_i) \exp(-r_i L_i - r_{i+1} L_i) / 2 \\ c &= (1-k_{i+1} r_{i+1} / k_i r_i) \exp(r_i L_i + r_{i+1} L_i) / 2 \\ d &= (1+k_{i+1} r_{i+1} / k_i r_i) \exp(r_i L_i - r_{i+1} L_i) / 2 \end{aligned} \quad \text{------------} \quad (数式2)$$

$$\begin{bmatrix} A_1 \\ B_1 \end{bmatrix} = \prod_{i=1}^{n-1} G_{i,i+1} \begin{bmatrix} A_n \\ B_n \end{bmatrix} \equiv \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} A_n \\ B_n \end{bmatrix} \quad \text{------------} \quad (数式3)$$

$$T_n(L_n, p) = \frac{Qf(p)\,[\exp(r_n L_n) + \gamma \exp(-r_n L_n)]}{k_1 (r_1 + h_0 / L_n)\,[(c+d\gamma) - e(a+b\gamma)]}$$

但し

$$e = \frac{(r_1 - h_0 / L_n)}{(r_1 + h_0 / L_n)}, \quad \gamma = \frac{(r_n + h_1 / L_n)}{(r_n - h_1 / L_n)} \exp(2 r_n L_n) \quad \text{------------} \quad (数式4)$$

[0038] The procedure of asking for the thermal diffusivity alpha with which are satisfied of the equation hereafter obtained by zero and Lycium chinense using the aforementioned

formula 4 which is a basic formula which gives the theoretical temperature response in a sample rear face in the thermal diffusivity alpha about the square deflection R with a temperature response, the specific heat c, or the partial differential about Biot several h, the specific heat c, or Biot several h by Newton's method is shown. The thermal diffusivity alpha of a heat-characteristic unknown layer, the specific heat c, or Biot several h are expressed as Variable x, it asks for deltax=-(delta R/delta x)/(delta2 R/delta x2), and x is updated by xnew = x+delta x. It can ask for x [alpha] which fills delta R/delta x= 0, i.e., a thermal diffusivity, the specific heat c, or Biot several h by repeating this procedure.

[0039] As mentioned above, in the theoretical temperature response of each class, a thermal diffusivity alpha and the heat capacity per unit volume (rho-Cp) appear. Therefore, if what is called for directly is these two heat-characteristic values (alpha, c) and thermal conductivity which is the product and density is known, specific heat at constant pressure will also be called for. However, it is also possible for an analysis top to deal with a constant and specific heat at constant pressure for the density of a heat-characteristic unknown layer as a variable, to multiply this specific heat at constant pressure by density after a calculation end, and to calculate the heat capacity per unit volume. In this numerical-analysis method, **1 dimension equation of heat conduction shall be materialized, and all heat-characteristic value and all bed depths other than the ** i-th layer with the respectively equal number of Biot in the front rear face of ** sample shall calculate under the prerequisite it is supposed that it is known. Thermal conductivity lambdai of each class in the steady state of ** multilayer material when applying the time constant method furthermore shown below It is dealt with as that in which relational expression with the whole thermal conductivity lambda is materialized in approximation.

[0040] This variable (alpha, c, h) can be defined according to the conditions which in the case of the multilayer material 10 as shown in <u>drawing 3</u> the ** thermal diffusivity alpha of a heat-characteristic unknown layer, the ** specific heat c, and three ** Biot several h variables are unknowns as a strange variable, and reduce one variable with the relational expression of h=g (alpha, c), and make the minimum deflection of a theoretical temperature response and a temperature response.

[0041] (Calculation of a time constant tau) When thickness is the monolayer material which is L, it is the property time t0. If a definition is given as t0 =L2/(pi 2 and alpha 0) It is t>>m-t0, using m as a constant. In the time domain t to satisfy After the 2nd term of a formula 5 (n>=1), since it becomes so small that it can ignore as compared with the first term, the theoretical solution of rear-face temperature can be approximated by the T(L, t)/Tm =A0 exp(-a0 and t) integralexp(a0 and t') f(t') dt' formula. here -- A0 =2beta02/(beta02+2 h+h2), and a0 =beta02 and alpha/L 2 it is .

[0042]

[Equation 2]

$$\frac{T(L,t)}{T_m} = \sum_{n=0}^{\infty} \frac{[(-1)^n 2\beta_n^2]\exp(-\beta_n^2 \alpha t/L^2)\int \exp(\beta_n^2 \alpha t'/L^2) f(t')\,dt'}{(\beta_n^2+2h+h^2)} = \sum_{n=0}^{\infty} A_n \exp(-a_n t)\int \exp(a_n t') f(t')\,dt' \quad \text{------------ (数式5)}$$

[0043] Therefore, when the logarithm of temperature response data is plotted to time and it asks for a time constant tau from the inclination, a time constant tau is a0. It can be considered that it is equal to the inverse number. That is, it is tau=1/a0 =L2/(beta02andalpha), and tau=1/a0 =L2/(beta02 and alphaav) is obtained as alpha av=alpha as that in which this relation is materialized also to average thermal-diffusivity alphaav of the multilayer material 10.
[0044] the case of monolayer material -- characteristic value betan about -- tan(betan) =2 h-

beta n / (betan2-h2) formula -- Biot several h -- beta 0 It can ask as a function and h0 =beta0 -(1/sinbeta0-1/tanbeta0) can be obtained by choosing a positive thing as a value of h. And beta 0 since this relation is similarly materialized about the multilayer material 10 It is given by beta0 =L/sqrt (alpha av-tau) using average thermal-diffusivity alphaav and the time constant tau of the multilayer material 10. That is, it can write as mentioned above as a function of average thermal-diffusivity alphaav and a time constant tau Biot several h, and since average thermal-diffusivity alphaav of the multilayer material 10 is the function of the strange thermal diffusivity alpha and the strange specific heat c in the multilayer material 10, it becomes possible [setting up Biot several h as h=g (alpha, c) as the whole].

[0045] It can measure by the direct method and time constant method which show below the strange heat constant contained in one arbitrary layer in the multilayer material 10. as [make / square deflection R of a theoretical temperature response and a temperature response / set up directly three variables (a thermal diffusivity alpha, specific heat c, Biot severalh) to search for, and / into the minimum / with a direct method,] (alpha --) It is the method of reaching the optimum solution of c and h, and a time constant method is a method of reducing a variable using asking for the time constant tau after passing time enough to the property time of the sample after laser radiation, and a thermal diffusivity alpha and Biot several h having a specific relation through the time constant tau. That is, it is the method of reducing one variable with the relational expression materialized between alpha, c, and h, and resulting in the minimum square deflection R.

[0046] the order square deflection I of a (b) which is defined as a lower formula as deflection here, the order square deflection II of a (b), the (c) reverse square deflection I, the (d) reverse square deflection II, and a (e) -- a logarithm -- each deflection R, such as square deflection, is employable suitably

(**) R=sigma (Q-Tj-Ej) 2 R= (sigma1/Ej2) and (sigma1/Tj2) -{sigma1/(Ej and Tj) (**) R= (sigmaEj 2) (sigmaTj 2), -(sigmaEj and Tj) 2 (**) R=sigma {(1/(Q-Tj))- (1/Ej)} 2 (**) } 2 (**) R=sigma 2 {ln(Q-Tj)-ln(Ej)} [0047] Q is the total energy absorbed by the sample of the laser pulse which irradiates the multilayer material 10 here. And when calculating about each above-mentioned deflection, it has each following feature.

(b) It is a general definition. What substituted for the (b) formula Q which can be found by delta R/delta Q= 0, and eliminated Q is used as deflection.

(b) Q which can be found by delta R/delta Q= 0 using the (b) type which is general deflection is substituted for a (b) formula, it is the deflection obtained by zero and Lycium chinense in the molecule portion, and there is an advantage to which a formula becomes easy as compared with a (b).

(c) Since the variable is concentrating on the denominator of theoretical temperature, a formula becomes easy by making it the inverse number. What substituted for the (c) formula Q which can be found by delta R/delta Q= 0, and eliminated Q is used as deflection.

Q which can be found from delta R/delta Q= 0 using a (d) (c) formula is substituted for a (c) formula, it is the deflection obtained by zero and Lycium chinense in the molecule portion, and there is an advantage from which a formula becomes easy as compared with a (c).

(e) a logarithm -- the minimal value can judge easily by considering as the square deflection of form What substituted for the (e) formula Q which can be found by delta R/delta Q= 0, and eliminated Q is used as deflection. In addition, Ej which corresponds by setting up two or more Laplace variables p, and carrying out the Laplace transform of the temperature response data to the set-up p in adopting Laplace-transform form in a (b) - (e) formula It shall ask and these shall be applied to a (b) - (e) formula.

[0048] (Measuring method of the heat constant by the time constant method) The procedure of the measuring method in a time constant method is shown below.

** Initial value calculation usual half-value value attainment time t1/2 of average thermal-diffusivity alphaav A method is followed and it is the maximum-temperature elevation value

Tm from the center-of-gravity position of a laser pulse heat input curve. Time to go up to half temperature is found, and initial value alphaav of an average thermal diffusivity is calculated from this value. Or the specific heat of a heat constant unknown layer and a thermal diffusivity may be set up, and the initial value of average thermal-diffusivity alphaav of multilayer material may be calculated based on it. Here, the mean specific heat cav in multilayer material and average thermal-diffusivity alphaav are given by the following formulas.

cav= (sigmarhoi Ci deltali)/ln alphaav=ln/(sigmadeltali/(rhoi Ci alphai)) (-cav)

However, deltali is the thickness (it is =li-li-1 and the whole multilayer material thickness ln is ln =sigmadeltali.) of the i-th layer in the multilayer material which consists of n layers.

[0049] ** Ask for a time constant tau from attenuation of measurement sample temperature in the time domain in which the approximation only by the first term of the time space theoretical solution of the sample rear-face temperature at the time of time passing enough and assuming that it is monolayer material after calculation laser pulse heat input of a time constant tau is materialized.

** The number initial value h0 of Biot Initial value h0 of a characteristic value formula to calculation average thermal-diffusivity alphaav, a time constant tau, and the number of Biot It asks.

** Set up two or more specific heat to a specific heat initializing heat constant unknown layer.

** Update the thermal diffusivity of a heat constant unknown layer by Newton's method using the square deflection R of the theoretical temperature response of the rear face of the multilayer material 10, and measurement temperature for which it asked using the laser pulse to the specific heat of thermal-diffusivity calculation plurality of the heat constant unknown layer by Newton's method. The average thermal diffusivity and the number of Biot of the multilayer material 10 are updated using the updated thermal diffusivity. And it calculates repeatedly using these values, and it calculates repeatedly until delta alpha/alpha becomes sufficiently small.

[0050] ** Calculate square deflection by the specific heat c calculated in the judgment of the minimum value of the square deflection R, and the reconfiguration aforementioned ** of two or more specific heat, the thermal diffusivity alpha, and Biot several h, and ask for the specific heat which gives the minimum value. The specific heat is reconfigured near the specific heat which gives the minimum value until ratio deltac/c with the intervals delta c and c of the specific heat which carried out the multi-statement becomes sufficiently small, and this is repeated and performed. Although the multi-statement of the specific heat c was carried out and it asked for the thermal diffusivity alpha corresponding to it by Newton's method in the above-mentioned procedure, you may exchange a thermal diffusivity alpha with the specific heat c. That is, it is good also as a method of carrying out the multi-statement of the thermal diffusivity alpha, and asking for the specific heat c corresponding to it by Newton's method. In this case, since it becomes an algebraic equation about the specific heat c, it is good also as a method of asking for the root analytically.

[0051] Drawing 6 is as a result of [at the time of changing the thickness of the strange layer in the multilayer material 10 which consists of three layers for which it asked by the describing / above / time constant method] calculation. (a) shows the example in case the heat constant strange to the 2nd layer whose (b) is an interlayer about the case where the heat constant with the 3rd strange layer of the lowest layer is included is included. clear from this drawing -- as -- (a) and (b) -- it turns out that a calculation error, i.e., a measurement error, can be dedicated in general at **1% or less of range in the case of which

[0052] (Measuring method of the heat constant by the direct method) A direct analysis method applies the least-squares method and Newton's method which were mentioned above about the deflection R written by the thermal diffusivity alpha, the specific heat c, and three Biot several h independent variables, and it asks for the thermal diffusivity alpha which fills

the minimum value of deflection R, the specific heat c, and Biot several h. Two examples of this procedure are shown below.

[0053] The procedure of setting up two or more numbers of Biot simultaneously according to direct-method 1 drawing 7 , and obtaining a desired heat constant is explained below.

** Initial value c0 of the specific heat It sets up (S-1).

** Carry out the multi-statement of the number of Biot (S-2).

** It is the minimum value Rj of the square deflection R to each number of BIO. It asks for the thermal diffusivity alpha to give and the specific heat c in the following procedure.

** To each of the specific heat by which -1 multi-statement was carried out, apply a least-squares method and Newton's method, and it is the minimum value Rj of deflection R. It asks for the thermal diffusivity to give (S-4). (S-3) Or the method of asking for the specific heat which carries out the multi-statement of the thermal diffusivity in S-3, and makes deflection R the minimum is also possible.

** Compare the deflection R for which it asked from class doubling of the -2 specific heat and a thermal diffusivity, and it is the minimum value Rj. The specific heat to give is chosen (S-6). (S-5)

** Set up two or more new specific heat in the direction which makes deflection R smaller near the specific heat which gave the -3 minimum value (S-3), and repeat from **-1. alpha and c when deltac/c becomes sufficiently small ask.

[0054] ** The minimal value Rj of deflection R It asks for the number of Biot to give in the following procedure.

** To the combination of the thermal diffusivity for which it asked by -1 each number of BIO, and process **, and the specific heat, ask for deflection R and it is the minimum value Ri of deflection R. The number of Biot to give is chosen (S-7).

** The -2 minimum value Ri The multi-statement of the new number of Biot is carried out in the direction which makes deflection R smaller near the given number of Biot (S-2), and process ** is carried out. h, alpha, and c when deltah/h becomes sufficiently small ask (S-8).

** The value hm of the aforementioned request, alpham, and cm It outputs. (S-9)

In the procedure of calculating the minimal value of the above deflection R, since the number of Biot, the specific heat, and a thermal diffusivity are equivalent independent variables, even if they exchange variables, they are materialized similarly. For example, it is good also as a method of asking for the thermal diffusivity which sets the number of two or more Biot as the inside which set up two or more specific heat, and gives the minimal value. Moreover, it is possible to ask for the thermal diffusivity, the specific heat, and the number of Biot which give the minimal value of deflection R also by Newton's method to two or more variables.

[0055] the specific heat c which is the unknown in the multilayer material 10 as shown in the direct-method 2** beginning at drawing 3 which boils further and can be set, and Biot several h -- suitable -- setting -- each initial value c0 and h0 It is set as the point (c0 and h0) on a h-c flat surface.

** Substitute for the theoretical temperature response F (alpha, c, h, t) and F' (alpha, c, h, p) each initial value (c0 and h0) set up above. It asks by making into delta R/delta alpha= 0 the value of the theoretical temperature response F containing Unknown alpha (alpha, c0, h0, t), F' (alpha, c0, h0, p) and actual temperature response E (t), and alpha that makes deflection R with E' (p) the minimum.

[0056] ** Ask by numerical-analysis methods, such as a least-squares method which mentioned above the value of alpha which fills alpha= delta R/delta 0 formula, and Newton's method. It is the initial value of alpha 0 and deflection R about the initial value of the thermal diffusivity alpha obtained at this time R0 It carries out and the group (R0, alpha 0, c0, and h0) of these initial value is set up as a group (Rm, alpham, cm, and hm) of the temporary minimum value.

** Set the group (c1 and h1) of a new value as the neighborhood of a point on the 2-

dimensional flat surface displayed by group (cm and hm) = (c0 and h0) of the minimum value. For a setup of this new point, operation of specifying the inside of the periphery within the criteria radius set up beforehand by the random number method can also be calculated and processed on a computer by making the point on the aforementioned 2-dimensional flat surface into the central point. Moreover, precision is raised by reducing this criteria radius gradually. Furthermore, it is also possible to set up two or more new updating values in the direction in which deflection or the difference of a heat constant updated becomes small using the group of two or more already set-up heat constants.

[0057] ** The above c1 and h1 A value is substituted for the theoretical temperature response F (alpha, c, h, t) and F' (alpha, c, h, p). It asks by making into delta R/delta alpha= 0 the value of alpha from which the deflection R with the theoretical temperature response F containing Unknown alpha (alpha, c1, h1, t), F' (alpha, c1, h1, p) and actual temperature response E (t), and E' (p) serves as the minimum. It is the value of alpha 1 and deflection R about the value of the thermal diffusivity alpha from which it is obtained at this time R1 It carries out and these groups (R1, alpha1, h1, and c1) are defined.

** Next, Rm (=R0) and R1 which have already been set up as the minimum value It compares and is R1. Rm In being large, it reconfigures a group [being new (c2 and h2)] near [said] group (cm and hm) = (c0 and h0) of the minimum value. R1 Rm case it is small -- Rm =R1 ** -- carrying out -- the minimum value Rm It updates.

** and the permissible-level value epsilon set up beforehand -- the minimum value Rm repeating the above operation until it becomes small -- the minimum value Rm It is made to decrease gradually, and when the minimum value Rm becomes smaller than the permissible-level value epsilon, it outputs as alpha, c, and h of a request of the group (Rm, alpham, cm, and hm) of the minimum value. In addition, the above operation is performed by carrying out data processing of the data of the temperature response obtained by computer which inputted the program of the above-mentioned operating procedure using a laser flash method.

[0058] Drawing 8 is as a result of [at the time of changing the thickness of the strange layer of the multilayer material 10 which consists of three layers for which it asked according to the above-mentioned direct method 2] calculation. (a) shows the case where (b) includes an example in case the heat constant strange to the 2nd layer which is an interlayer is included for the heat constant with the 3rd strange layer of the lowest layer. clear from this drawing -- as -- (a) and (b) -- it turns out that the range of the accuracy of measurement by which a calculation error, i.e., a measurement error, is generally needed in the case of which is fulfilled

[0059] As mentioned above, although the example of this invention was explained, all of change of conditions which this invention is not limited to these examples and does not deviate from a summary are the scopes of this invention. For example, in this example, although the case where carried out the Laplace transform of the data of a theoretical temperature response and a temperature response, and they were processed was explained, you may process in the usual time space. moreover, the order square deflection from which the feature differs if needed in the deflection of the theoretical temperature response and temperature response which are applied to this invention, reverse square deflection, and a logarithm -- square deflection etc. is employable Furthermore, it is considered that three variables, the thermal diffusivity which is the unknown contained in the formula of the deflection of a theoretical temperature response and a temperature response, the specific heat, and the number of Biot, are right within the limits of this invention similarly when using each mathematically the relational expression which exchanged each variable arbitrarily in relational expression which was explained in the above-mentioned example, since it is an equivalent variable.

[0060]

[Effect of the Invention] Can set to a laser flash method according to claim 1 to 5, and it sets

to the measuring method of a heat constant, and its equipment. The deflection of the theoretical temperature response which sets up a thermal diffusivity alpha, the specific heat c, and Biot several h, and is obtained, and an actual temperature response is compared. While being able to determine the value of the unknown which updates the value of an unknown efficiently serially and fills the measurement data of an actual temperature response asymptotically with high degree of accuracy The absolute value of a temperature response is not needed like before, but it can ask for the strange heat constant in multilayer material based on the measurement data of a relative temperature response. Furthermore, it is minimum deviation Rm about Biot severalh and the specific heat c, using deflection of a theoretical temperature response and the temperature response actually obtained as an index. Since it sets up serially near the value to give and minimum deviation is updated, the true value of the strange number of Biot, the specific heat, and a thermal diffusivity can be calculated by composition of a simple repeat calculation means, and data processing by the computer can carry out at high speed.

[0061] Especially, in the measuring method of a heat constant using the laser flash method according to claim 2, it can ask for deflection R by the ability making a thermal diffusivity, the specific heat, and the number of Biot into a variable, and the value of alpha, c, and h can be calculated correctly and quickly as what gives the minimal value of this deflection. Furthermore, in the measuring method of a heat constant using the laser flash method according to claim 3, since the initial value of the number of Biot is set up based on the relation between the time constant in a temperature response, and the value of half-value value attainment time t1/2 etc., while being able to set up beforehand near the true value and being able to cut down the number of times of calculation sharply, the heat constant for which it asks does not emit.

[0062] Moreover, it sets to the measuring device of a heat constant using the laser flash method according to claim 4. It is minimum deviation Rm about Biot severalh and the specific heat c, using deflection R of a theoretical temperature response and the temperature response actually obtained as an index. It sets up serially near the value to give. Minimum deviation Rm Since it can update and the true value of the strange number of Biot, the specific heat, and a thermal diffusivity can be calculated by composition of a simple calculation means It is rare to be able to measure to a hot temperature region using the radiation thermometer which can measure sample temperature, and to be influenced by the environmental condition of measurement, without not measuring absolute temperature and contacting a sample. Furthermore, it sets to the measuring device of a heat constant using the laser flash method according to claim 5. Since the number of Biot is updated based on a thermal diffusivity and the specific heat, deflection R of a theoretical temperature response and the temperature response actually obtained is made into an index. It is minimum deviation Rm about a thermal diffusivity alpha or the specific heat c. It sets up serially near the value to give and is minimum deviation Rm. Since it can update and the true value of the strange number of Biot, the specific heat, and a thermal diffusivity can be calculated by the repeat of a few operation calculation means, a calculation error can be decreased.

Biot number (h), specific heat (c), and thermal diffusivity α of the unknown layer can be obtained.

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